(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 739 017 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
11.08.1999 Bulletin 1999/32

(51) Int Cl.[6]: G21F 1/12, G21F 5/015

(21) Application number: 96106016.7

(22) Date of filing: 17.04.1996

(54) **Apparatus for preparing a radioactive solution using a radiation shielding member and method of manufacturing such a shielding member**

Einrichtung zur Vorbereitung einer radioaktiven Lösung mit einem Abschirmkörper und Verfahren zur Fertigung eines solchen Abschirmkörpers

Dispositif de préparation d'une solution radioactive comportant un corps de blindage et méthode de fabrication d'un tel corps de blindage

(84) Designated Contracting States:
CH DE FR GB IT LI

(30) Priority: 20.04.1995 JP 11915595
19.03.1996 JP 6317196

(43) Date of publication of application:
23.10.1996 Bulletin 1996/43

(73) Proprietor: NIHON MEDI-PHYSICS Co., Ltd.
Nishinomiya-shi, Hyogo-ken (JP)

(72) Inventors:
- Okano, Sakae, c/o Nihon Medi-Physics Co., Ltd.
Sodegaura-shi, Chiba-ken (JP)
- Obata, Fumihiro
Tokyo-to (JP)
- Ohya, Masato, c/o Nihon Medi-Physics Co., Ltd.
Sanda-shi, Hyogo-ken (JP)
- Tanaka, Yoshimasa,
c/o Nihon Medi-Physics Co., Ltd
Sodegaura-shi, Chiba-ken (JP)

(74) Representative: VOSSIUS & PARTNER
Siebertstrasse 4
81675 München (DE)

(56) References cited:
EP-A- 0 096 918
EP-A- 0 220 937
EP-A- 0 314 025
EP-A- 0 555 919
EP-A- 0 586 368
US-A- 3 535 085

- DATABASE WPI Week 8817, Derwent Publications Ltd., London, GB; AN 88-115722, XP002005376 & JP-A-63 061 999 (TOSHIBA) 18 March 1988
- PATENT ABSTRACTS OF JAPAN vol. 016, no. 225 (P-1360) 26 May 1992 & JP-A-04 047 296 (MITSUBISHI HEAVY IND LTD) 17 February 1992

EP 0 739 017 B1

Description

[0001] The present invention relates to a manufacturing method for a radiation shielding member for radioactive substances, particularly for use in containers or the like to transport radioactive solution for medical use, and furthermore relates to an apparatus for producing radioactive solution equipped with the shielding member.

[0002] While there are containers of various shapes and various materials that are equipped with shielding members for a radioactive substance, radiation shielding members of transportation containers used to transport or preserve vials, ampoules, so-called prefilled syringes filled with medical radioactive solution and the like or shielding members used in radioactive solution-producing apparatuses called generators are generally known to be formed of lead alone.

[0003] Under the present situation, shielding ability of these kinds of shielding members is secured by thickening a shielding body if a level of radioactivity of a to-be-stored radioactive substance is increased. Alternatively, the shielding members are sometimes stored in larger shielding members to transport the container in order to ensure the shielding ability.

[0004] When the shielding body is made thickly, the shielding member itself becomes bulky in size and heavy-weight, which causes inconveniences to handle the container equipped with the shielding member. Moreover, when the general shielding member is accommodated in a much larger shielding member, both the weight and the volume are greatly increased, with the other disadvantages accompanied.

[0005] Although the shielding member may be light in weight and compact when tungsten showing higher shielding ability against radioactivity than lead is used as a material for the shielding body as compared with when lead is used, tungsten is expensive and therefore uneconomic if the entire shielding body is made of tungsten. So, tungsten cannot be employed for a large shielding member.

[0006] It is also complicate and uneconomic to manufacture shielding members cf different shielding ability in accordance with kinds and radioactive intensities of to-be-stored radioactive substances.

[0007] JP-A-04047296 teaches an overpack canister of a composite material of stainless steel and cast iron which is designed to store a stainless steel canister for storing of processed waste including radioactive waste in an outer vessel. The aim is to make the canister resistive to the underground water and soil for several hundreds to a thousand years. In order to achieve the aim, the document teaches a double structure of stainless steel (outer body) and cast iron (inner body) for the outer vessel. The stainless steel canister is stored in the outer vessel, and an upper part of the canister is tightly sealed by fused lead.

[0008] JP-A-63061999 teaches a member for shielding X rays from an X-ray source and has for its object to provide an X-ray shielding member which hardly re-emits X rays with exerting sufficient shielding effects. In order to achieve the object, the document overlaps a plurality of members of different X-ray absorption edges. A combination of lead (at the side closer to the X-ray source) and tungsten is employed by way of example.

[0009] EP-A-586368 teaches a radioactive solution generator. However, the document intends to provide a generator which is easy to manipulate and transport, is recyclable and ensures high safety to radiation leak, radioactive contamination, etc. For this purpose, an inner shielding vessel storing the column and an outer shielding vessel storing the inner shielding vessel are constituted separately according to the document. The outer shielding vessel and inner shielding vessel storing the column are thus fitted and removed easily, so that the column part is exchanged with ease.

[0010] EP-A-314025 is directed to a cask for transporting radioactive material (waste), with an aim to transport a maximum quantity of radioactive material within a predetermined weight limit (not exceeding approximately 22680 kg (50000 pounds) including contents). In order to accomplish the aim, the cask of the document adopts titanium alloy for a structure wall, either of depleted uranium, lead and tungsten for an inside shielding wall, and boron particles distributed in a silicon base for an outside shielding material, thereby to reduce the weight of the cask structure and improve the safety of the cask as a whole.

[0011] An object of the present invention is therefore to provide a manufacturing method for a shielding member for radioactive substances which can be small in size and light in weight while holding the same shielding ability as the conventional art, or which can enhance the shielding ability when it is of the same size as the conventional art, thereby can store radioactive substances of higher radioactive intensities and which can change shielding ability in accordance with the change in kinds and intensities of to-be-stored radioactive substances, with eliminating the aforementioned disadvantages inherent in the conventional art. The present invention aims also to provide an apparatus for producing radioactive solution using the above shielding member. These objects are achieved with the features of the claims.

[0012] The applicant has accomplished the shielding member of the embodiment through a discovery that a combination of two or more kinds of radiation shielding materials of different shielding abilities enables a container to be lightweight while maintaining a leak dose from the container at the same level as a conventional standard.

[0013] These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view showing the structure of an apparatus for producing radioactive solution which uses a

radiation shielding member according to one embodiment of the present invention, with the radiation shielding member being represented in a sectional view taken along a line XV-XV in Fig. 3;
Fig. 2 is a sectional view showing the structure of the radioactive solution-producing apparatus of Fig. 1 according to a different embodiment;
Fig. 3 is a plan view of the radiation shielding member in the radioactive solution-producing apparatus of Figs. 1 and 2;
Fig. 4 is a plan view of the radioactive solution-producing apparatus shown in Figs. 1 and 2;
Fig. 5 is a sectional view of a mold for explaining a manufacturing method for a container part of the radioactive solution-producing apparatus of Fig. 1;
Fig. 6 is a sectional view of a mold for explaining a manufacturing method for a container part of the radioactive solution-producing apparatus of Fig. 2;
Fig. 7 is a sectional view of a radioactive solution transportation container using a radiation shielding member according to one embodiment of the present invention;
Fig. 8 is a sectional view of the radioactive solution transportation container of Fig. 7 according to a different embodiment of the present invention;
Fig. 9 is a graph of a relation between the thickness of tungsten and lead and a leak dose; and
Fig. 10 is a graph of a relation between the stored radioactivity and a leak dose.

[0014] Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.
[0015] A shielding member for a radioactive substance, a manufacturing method for the shielding member and a radioactive solution-producing apparatus using the shielding member according to preferred embodiments of the present invention will be described below with reference to the drawings.
[0016] A radiation shielding member of the present invention has a lid part and a container part of shielding bodies formed of radiation shielding materials. The lid part is formed of one or a plurality of radiation shielding materials, while the container part is formed of a plurality of radiation shielding materials.
[0017] At least either the lid part or the container part of the above shielding member comprises a plurality of shielding bodies of two or more kinds of radiation shielding materials of different shielding abilities.
[0018] Further, the radiation shielding member is characterized in that the shielding body formed of a radiation shielding material of a higher shielding ability is arranged at an inner side of a container, and the shielding body of a radiation shielding material of a lower shielding ability than that of the above shielding material is disposed outside the above shielding body.
[0019] A radiation shielding member using at least two or more kinds of shielding materials of different shielding abilities selected from lead, tungsten and depleted uranium is a suitable example of the above radiation shielding member. Particularly, a combination of tungsten and lead or a combination of depleted uranium and lead is ideal.
[0020] In the radiation shielding member according to the embodiment of the invention, one or all of the inner shielding bodies constituting at least either one of the lid part and the container part is an independent molded body and may be designed to be exchangeable. Alternatively, a part or the whole of a plurality of shielding bodies constituting either one of the lid part and the container part may be integrally molded in one body.
[0021] A radioactive solution transportation container having a storing part for storing a radioactive solution vessel, and a radioactive solution-producing apparatus in which a radiation shielding member is provided with a column containing at least a parent radioactive nuclide, an eluant feed means and a radioactive solution discharge means are preferred embodiments of the present invention.
[0022] A further feature of the present invention relates to a manufacturing method for the container part of the radiation shielding member, whereby a mold corresponding to the container part of the radiation shielding member is prepared, a projecting part of the mold corresponding to a space for storing a radioactive substance is coated with a preliminarily formed shielding body of a radiation shielding material having a sufficiently higher melting temperature than a radiation shielding material to be injected later into the mold, and then the radiation shielding material of a lower melting temperature than the above radiation shielding material is injected into the mold, thereby casting the container part in one body.
[0023] The radiation shielding member of the embodiment may be applicable to radioactive substances of approximately several mCi to several tens mCi radioactivity. However, it is complicate in manufacturing and poor in cost performance, consequently not advantageous in terms of the size and weight to combine shielding bodies of a plurality of radiation shielding materials in order to constitute a shielding member for radioactive substances having low radioactivity. Therefore, it is furthermore effective to apply the shielding member of the embodiment to storage of radioactive substances of, e.g., several hundreds mCi or higher radioactivity.
[0024] A shielding member for a radioactive solution-producing apparatus for medical use (technetium-99m generator) 100 as shown in Fig. 1 is one preferred embodiment. Molybdenum-99 that elutes a radioactive solution of

100-300mCi (3.7-11.1 GBq) technetium-99m at a calibration time is stored in the generator 100.

[0025] Radiation shielding materials used for the above shielding member are, e.g., lead, tungsten, depleted uranium, boron steel, boron stainless steel, cadmium, stainless steel, concrete, plastics, etc. One or more of the shielding materials is properly selected in accordance with the kind(s) and amount of radioactivity of the radioactive substance to be stored in the shielding member. On the other hand, it is better to combine and use two or more kinds of γ-ray shielding materials, for example, chosen from lead, tungsten and depleted uranium for the medical radioactive solution transportation container or the radioactive solution-producing apparatus. A combination of lead and tungsten or a combination of lead and depleted uranium is favorable because of its good shielding ability. Especially, tungsten and lead are preferred as the shielding material of the shielding member for the medical radioactive solution-producing apparatus or medical radioactive solution transportation container from the viewpoint of the manufacturing convenience, handling easiness and cost.

[0026] In comparison with 11.3g/cm^3 density of lead, densities of tungsten and depleted uranium are large, specifically, 19.3g/cm^3 and 19.0g/cm^3. Therefore, it is desirable to arrange tungsten or depleted uranium having high shielding ability at the inner side of the shielding member so as to make the shielding member light-weight.

[0027] A relation between a thickness of tungsten and lead and a leak dose is indicated in Fig. 9.

[0028] As is clearly understood from the line A-B in Fig. 9, if the leak dose is constant, lead may be thinned by increasing a thickness of tungsten.

[0029] Also as is apparent from the line C-D, when the total thickness of the shielding body formed of a combination of tungsten and lead is constant, the leak dose can be reduced by increasing the thickness of tungsten.

[0030] In Fig. 9, each symbol means the following :

[0031] The symbol "○" shows the leak dose in a case that a container is made of lead only. The symbols "▲", "□" and "♦" show the leak doses in a case that a container is formed of a shielding body of lead and shielding body of tungsten disposed closely to the shielding body of lead. The symbol "▲" is a case of tungsten having thickness of 10mm, "□" having thickness of 15mm, and "♦" having thickness of 20mm, respectively.

[0032] In the case where charged particles are emitted from a radioactive source, it is effective to shield the radioactive source by means of a low-density substance to restrict the generation of braking X-rays. At the same time, since some shielding materials like lead are soft and weak to shocks or exert metallic toxicity, and for the sake of handling and transportation convenience, it is desired to coat the surface or exposed surface of the shielding material with plastic or the like if the shielding material is depleted uranium, lead, etc.

[0033] As will be described in detail later, it is favorable to form inner shielding bodies and other shielding bodies of the shielding member independently and use the bodies in combination to allow one or all of the inner shielding bodies to be easily exchanged, detached or fitted. In this case, the thickness of the shielding body forming the storing part in the shielding member is changed or the kind of the radiation shielding material is selected in accordance with the kind (s) and amount of radioactivity of the radioactive substance stored in the storing part, whereby the leak dose from the shielding member is regulated and the shielding member is made light in weight without changing outer dimensions of the shielding member. Even if the kind(s) or amount of radioactivity of the radioactive substance stored in the shielding member is changed, the one type of the shielding member meets the case, i.e., the shielding member is advantageously versatile for general purpose and therefore economic.

[0034] A concrete example of the shielding member for a radioactive substance of the embodiment will be depicted hereinbelow with reference to the drawings when used in a technetium-99m generator that corresponds to the radioactive solutionproducing apparatus. Fig. 3 is a plan view of a radiation shielding member 101 shown in Figs. 1 and 2. The radiation shielding member 101 in Figs. 1 and 2 is shown as a sectional view taken along a line XV-XV of Fig. 3.

[0035] In the radioactive solution-producing apparatus (technetium-99m generator) 100 in Fig. 1, the radiation shielding member 101 comprising a lid part 4 and a container part 5 of shielding bodies of radiation shielding materials is provided with an alumina column 1 having molybdenum-99 as a parent radioactive nuclide adsorbed thereto, an eluant feed means 8 having an eluant feed port 8a to which a vial 2 filled with isotonic sodium chloride solution is fitted, a radioactive solution discharge means 9 having an eluate discharge port 9a, etc. A vacuum vial 3 to collect technetium-99m solution as a daughter radioactive nuclide eluted from molybdenum-99 is set to the discharge means 9.

[0036] The container part 5 is generally a circular cylinder, having a first recessed part 6 and a second recessed part 7 at a central part thereof. The first recessed part 6 has a small depth in an axial direction of the container part 5. The second recessed part 7 formed at a bottom part 6a of the first recessed part 6 for accommodating the alumina column 1 therein is smaller in diameter than the first recessed part 6 and has a large depth in the axial direction of the container part 5. A peripheral part 5b of the second recessed part 7 is formed of a cylindrical tungsten shielding body 51 of a predetermined thickness and a predetermined length from a bottom surface of the bottom part 6a in an axial direction of the second recessed part 7. The tungsten shielding body 51 corresponds to one embodiment of the second on side shielding body. The tungsten shielding body 51 may be formed over the entire length in the axial direction of the second recessed part 7. In the instant embodiment, however, since the alumina column 1 is used, having molybdenum-99 adsorbed only to a part of a relatively upper part thereof, the shielding body 51 extends over approximately 60-70%

of the total length of the second recessed part 7 from the bottom surface of the bottom part 6a as the shielding ability and weight are taken into consideration, as shown in the drawing. A bottom part 5c of the second recessed part 7 of a predetermined thickness in the axial direction is provided with a tungsten shielding body 52 that is an embodiment of the bottom shielding body. The tungsten bottom shielding body 52 also corresponds to one embodiment of the second shielding body. A remaining part 5a of the container part 5 excluding the peripheral part 5b and the bottom part 5c is formed of lead. The container part 5 is constituted of the lead part 5a, peripheral part 5b of tungsten and bottom part 5c of tungsten. The lead part 5a is an example of the first shielding body.

[0037] The alumina column 1 is properly supported and accommodated in the second recessed part 7, for example, by a projecting part (not shown) formed at an inner peripheral surface 51a of the tungsten shielding body 51. To the alumina column 1 are connected as indicated in the drawing the eluant feed means 8 for feeding isotonic sodium chloride solution from the vial 2 to the alumina column 1 and the radioactive solution discharge means 9 for guiding technetium-99m solution eluted by the supplied eluate to the vacuum vial 3.

[0038] The lid part 4 consists of an outer shielding body 4a made of lead, an inner shielding body 4b made of lead and a shielding body 41 made of tungsten. The inner shielding body 4b is seated in the first recessed part 6. The above outer shielding body 4a and inner shielding body 4b are embodiments of the third shielding body, while the tungsten shielding body 41 corresponds to an embodiment of the fourth shielding body. A space 6b is defined in the inner shielding body 4b to allow the feed means 8 and the discharge means 9 to extend. A recessed part 4c of a circular cylinder is formed at a bottom surface 4d of the inner shielding body 4b facing an opening 7a of the second recessed part 7, into which the tungsten shielding body 41 is fitted. Other parts than the recessed part 4c of the inner shielding body 4b are formed of lead.

[0039] The outer shielding body 4a is generally in the shape of a disc covering an upper surface of the container part 5 with the inner shielding body 4b fitted in the first recessed part 6. Spaces 42 and 43 are secured to extend the feed means 8 and the discharge means 9 in the outer shielding body 4a.

[0040] The lid part 4 and the container part 5 are accommodated in a plastic exterior container 10 of a generally box-like shape. An upper part 10a of the exterior container 10 to which the isotonic sodium chloride solution vial 2 and the vacuum vial 3 are attachable is detachably coupled by an engaging means (not shown) with a lower part 10b housing the lid part 4 and the container part 5.

[0041] According to the embodiment, the lid part 4 is formed schematically like a disc, similarly, the container part 5 being generally cylindrical, the tungsten shielding body 41 of the recessed part 4c being disc-shaped, the first recessed part 6 and second recessed part 7 being circular in the outer form, the tungsten shielding body 51 cylindrical and the tungsten shielding body 52 being disc-shaped. However, each of these parts is not restricted in shape to the above embodiment. For instance, the lid part 4 and the container part 5 may be polygonal, the tungsten shielding body 51 may be a prism, or the tungsten shielding body 51 may be integrally molded with the tungsten shielding body 52 into the shape of a cup, or the recessed part 4c and the bottom part 5c may be in other shapes than a disc.

[0042] In using the radioactive solution-producing apparatus 100, in the first place, the isotonic sodium chloride solution vial 2 is set at the eluant feed port 8a of the feed means 8, and the vacuum vial 3 is fitted at the eluate discharge port 9a of the radioactive solution discharge means 9. In the arrangement as above, the isotonic sodium chloride solution in the vial 2 passes through the feed means 8 to the alumina column 1 because of the vacuum pressure of the vacuum vial 3. As a result, the solution including the daughter radioactive nuclide, i.e., technetium-99m eluted from the alumina column 1 is collected in the vacuum vial 3 through the discharge means 9.

[0043] Now, a relation between the thickness of the shielding body of a combination of two kinds of radiation shielding materials and the weight of the shielding body will be discussed with respect to the above shielding member of the structure in the radioactive solution-producing apparatus 100 (technetium-99m generator). More specifically, while molybdenum-99 of 200mCi radioactivity is kept in the alumina column 1, a leak dose in a first container for measuring having a lid part and a container part corresponding to the lid part 4 and the container part 5 formed only of lead is measured. Then, a relation between the thickness and the weight of each shielding member formed of a combination of a lead shielding body and a tungsten shielding body to secure the same shielding ability as the above first container for measuring is checked. The results are indicated in Table 1 in which "an upper surface", "a side surface" and "a bottom surface" of the lead shielding body correspond to [I], [II] and [III] in Fig. 1, and "an upper surface", "a side surface" and "a bottom surface" of the tungsten shielding body correspond to [IV], [V] and [VI] in Fig. 1, respectively.

TABLE 1

Container for measuring		1st	2nd	3rd	4th	5th
Thickness of lead;	Upper surface (mm)	45	30	22	15	0
	Side surface (mm)	40	25	17	10	0
	Bottom surface (mm)	17	2	0	0	0
Thickness of tungsten;	Upper surface (mm)	0	10	15	20	30
	Side surface (mm)	0	10	15	20	27
	Bottom surface (mm)	0	10	12	12	12
Total weight (g)		9798	7518	7216	7627	7812
Weight ratio		1	0.77	0.74	0.78	0.80

(The weight ratio is calculated based on the weight of the 1st container for measuring as a reference.)

[0044] As is made clear from Table 1, in the 5th measuring container using 30mm-thick tungsten as compared with the 1st measuring container having both the lid part and the container part totally formed of lead, the outer shape is made smaller and the weight is reduced. It is expensive if the whole of the lid part and the container part is formed of tungsten.

[0045] On the other hand, when lead and tungsten shielding bodies are used in combination as in the 2nd-4th meas-

uring containers, the weight is furthermore reduced than in the 5th measuring container consisting of the lid part and the container part totally formed of tungsten. That is, while the 1st measuring container weighs about 10kg, the weight of each of the 2nd-4th measuring containers is reduced to about 7.2-7.6kg. Therefore, the radioactive solution-producing apparatus using the above type of radiation shielding member is more convenient to carry with, as compared with the conventional one.

[0046] The above fact eventually confirms that it is effective to combine two kinds of radiation shielding materials to secure the shielding ability and lighten the shielding member.

[0047] Meanwhile, an 11th measuring container was prepared by decreasing the lead thickness of the 1st measuring container from 40mm to 30mm and providing the peripheral part 5b of Fig. 1 with 10mm-thick tungsten thereby to set the above region [II] to be 40mm. A relation between the amount of radioactivity and a leak dose was detected for each of the 11th and 1st measuring containers. The leak dose of the 11th measuring container is, as shown in Fig. 10, approximately 60% of the technetium-99m generator formed solely of lead which corresponds to the 1st measuring container. If the leak dose of the 11th measuring container is kept equivalent to that of the 1st measuring container, the 11th measuring container can store radioactive substances of nearly 1.5 times an amount of radioactivity of the 1st container.

[0048] Subsequently, when the radioactivity in the alumina column 1 is increased 1.5 times from 200mCi (7.4GBq) to 300mCi (11.1GBq), a thickness, a weight and a weight ratio of each shielding body of the 6th-10th measuring containers to secure the equivalent shielding ability to that of the 1st container are shown in Table 2.

[0049] Since it is necessary to increase the thickness of shielding bodies of the 6th measuring container wherein all of the shielding bodies are formed of lead so as to ensure the shielding ability, the weight of the 6th measuring container becomes nearly 1.2 times, i.e., approximately 12kg that of the 1st measuring container.

[0050] In the meantime, when the shielding body of 10mm-thick tungsten is combined with the lead shielding body as in the 7th measuring container, the thickness of each shielding body and the leak dose (shielding ability) are similar to those of the 1st measuring container. Moreover, the weight becomes about 80% of that of the 6th measuring container in which all shielding bodies are formed of lead. Accordingly, the 7th measuring container achieves shielding against higher radioactivity by the shielding member of the same shielding ability and the same weight as the conventional art.

TABLE 2

Container for measuring		6th	7th	8th	9th	10th
Thickness of lead;	Upper surface (mm)	49	34	26	19	0
	Side surface (mm)	44	29	21	14	0
	Bottom surface (mm)	21	6	0	0	0
Thickness of tungsten;	Upper surface (mm)	0	10	15	20	33
	Side surface (mm)	0	10	15	20	30
	Bottom surface (mm)	0	10	14	14	14
Total weight (g)		12122	9502	8575	9193	9435
Weight ratio		1.24	0.97	0.88	0.93	0.96

(The weight ratio is calculated based on the weight of the 1st measuring container as a reference.)

[0051] From the foregoing results, it is confirmed that combining two kinds of radiation shielding bodies made of tungsten and lead is effective to improve the shielding ability and to increase an amount of radioactivity to be stored while securing a constant shielding ability.

[0052] In the radioactive solution-producing apparatus 100 shown in Fig. 1, as described before, since the peripheral part 5b of the second recessed part 7 is a simple cylinder with having a smaller diameter than that of the inner shielding body 4b as illustrated in the drawing, the tungsten shielding body 51 at the peripheral part 5b of the container part 5 can be pulled out in the axial direction of the second recessed part 7 and exchanged with other members of tungsten or other materials of a smaller thickness than the tungsten shielding body 51.

[0053] At the same time, since the tungsten shielding body 41 fitted in the recessed part 4c of the inner shielding body 4b is like a disc and slightly projected from the bottom surface 4d, the shielding body 41 is exchangeable with a thinner shielding body and accordingly rendered lighter in weight without changing the outer diameter of the inner shielding body 4b.

[0054] Because of the exchangeability of the shielding bodies 51 and 41 at the peripheral part 5b and recessed part 4c as described hereinabove, when the radioactive substance to be stored in the recessed part 7 is low in radioactive intensity, the shielding body at the peripheral part 5b may be formed of, e.g., lead. In contrast, if the radioactive intensity of the stored substance is high, the lead shielding body can be thickened or replaced with a tungsten shielding body. If the radioactivity is still much higher, the shielding body of tungsten may be increased in thickness. In other words, even when the radioactivity of the radioactive substance stored in the second recessed part 7 is changed, one kind of the shielding body at the lead part 5a of the container part 5 and one kind of the exterior container 10, etc. are sufficient, which makes the producing apparatus economic with improvement of convenience in practical use. Furthermore, the shielding body at the bottom part 5c may be made exchangeable, the second recessed part 7 may be formed of one cup-like shielding body, or the thickness or the kind of the radiation shielding material of the cup-like shielding body may be changed.

[0055] For instance, if the shielding body at the peripheral part 5b may be allowed to be thin, a light-weight member such as plastic or the like is inserted between the shielding body at the peripheral part 5b and the lead part 5a thereby to reduce the weight.

[0056] If it is not necessary to change the shielding bodies as above, shielding bodies formed separately from each other may be fixed by bonding or the like manner into one body.

[0057] Depleted uranium may be used in place of tungsten as the shielding material.

[0058] Although detailed later, when the shielding member is manufactured by an integral casting method whereby the shielding body at the peripheral part 5b is formed of tungsten, etc. beforehand and, lead or the like radiation shielding material is injected into the part 5a outside the peripheral part 5b, this method restricts manufacturing costs and facilitates the manufacture. Moreover, the method is suitable to cast and form the inner shielding body because tungsten not only shows a higher shielding ability, but has a sufficiently higher melting point than lead. Tungsten is melted approximately at 1800°C while the melting point of lead is about 300°C.

[0059] The foregoing description related to the exchange and the manufacturing method of shielding bodies is similarly applicable to a radiation shielding member storing a radioactive solution container to be described later.

[0060] A radioactive solution-producing apparatus 110 as shown in Fig. 2 is devisable as another embodiment of the radioactive solution-producing apparatus 100. A difference of the apparatus 110 from the apparatus 100 is that the size of the shielding bodies at the recessed part 4c and the bottom part 5c is changed, a coupling member 122 is installed in the axial direction of the second recessed part 7 so as to form the second recessed part 7, and a shielding body 123 is added at the bottom part of the container part 5. The same structural parts are designated by the same reference numerals in Figs. 1 and 2.

[0061] A shielding body 120 corresponding to the shielding body at the recessed part 4c is designed to have a little larger outer diameter XI than an inner diameter of the second recessed part 7 and a larger thickness or depth VII in the axial direction of the second recessed part 7. A shielding body 121 corresponding to the shielding body 52 at the bottom part 5c has a larger outer diameter X than the inner diameter of the second recessed part 7. In the present embodiment, the thickness VII of the shielding body 120 exceeds a thickness VIII of the shielding body 51 at the peripheral part 5b. Further, the outer diameter X of the shielding body 121 is almost the same as the outer diameter of the shielding body 51 at the peripheral part 5b, and a thickness or depth IX of the shielding body 121 is approximately equal to the above thickness VIII. The outer diameter X of the shielding body 121 is made larger than the inner diameter of the shielding body 51 so as to easily manufacture of the shielding member according to a manufacturing method to be described later.

[0062] Concretely, the outer diameter XI of the shielding body 120 is 18mm, the thickness VII is 16mm, whereas the thickness VIII of the shielding body 51 is 10mm and a length XII is 50mm. The outer diameter X of the shielding body 121 is 35mm and the thickness IX is 11mm.

[0063] The coupling member 122 is a stainless steel pipe having the same inner diameter as the second recessed part 7 and connects a bottom surface 124 of the side shielding body 51 at the peripheral part 5b with an upper surface

125 of the bottom shielding body 121. The coupling member 122 is arranged on the same axis as the second recessed part 7. Accordingly, the second recessed part 7 is constituted of the shielding body 51 at the peripheral part 5b, the coupling member 122 and the shielding body 121.

[0064] Now, a manufacturing method for the shielding member will be discussed below in the example of the above producing apparatuses 100 and 110.

[0065] As indicated in Fig. 5, in a mold 21 used for forming the container part 5 of the shielding member of the producing apparatus 100, a core pin 22 of an inverted-T cross section is set within a recessed part 24 defined to form the lead part 5a. The core pin 22 is composed of a disc-like part 25 to form the first recessed part 6 and a columnar part 26 to form the second recessed part 7. The columnar part 26 is erected at the disc-like part 25 and integrally molded with the disc-like part 25. The tungsten shielding body 51 corresponding to the peripheral part 5b is fitted on the columnar part 26 and at the same time, the tungsten shielding body 52 corresponding to the bottom part 5c is mounted at a front end part 26a of the columnar part 26.

[0066] Lead is injected through a sprue 20 into the mold 21. As referred to earlier, the melting point of tungsten is sufficiently higher than that of lead, and therefore, tungsten is never melted when lead is injected. In the case where the tungsten shielding body is provided not all over the length in the axial direction of the second recessed part 7, but a required shorter length than the total length of the second recessed part 7 from the viewpoint of the shielding ability, injected lead may sometimes enter a small gap 23 between a peripheral surface 26b of the columnar part 26 and an inner peripheral surface 51a of the shielding body 51, whereby a resultant molded article is hindered from separating from the columnar part 26.

[0067] Although tungsten may be coated all over the length of the columnar part 26 in order not to form the above gap 23, it is more economical to decrease a using amount of expensive tungsten as much as possible. As such, stainless steel which is inexpensive in comparison with tungsten and has a sufficiently higher melting temperature (about 1300°C) than lead, or the like material may be used for parts not requiring tungsten thereby to cover the columnar part 26 completely. A radioactive solution-producing apparatus manufactured according to the manufacturing method which prevents the generation of the above gap 23 corresponds to a shielding member 111 of the producing apparatus 110. The radioactive solution-producing apparatus 110 is provided with the coupling member 122 of the stainless steel pipe, as mentioned earlier, between the bottom surface 124 of the side shielding body 51 and the shielding body 121 at the front end part 26a of the columnar part 26. As shown in Fig. 6, the stainless steel coupling member 122 is provided at the columnar part 26 between the shielding body 51 and the bottom shielding body 121 in a mold 31 for forming the container part 5 of the shielding member 111 of the producing apparatus 110. In the constitution as above, the generation of the gap 23 is avoided. The molded article is consequently easily detached from the columnar part 26.

[0068] After the container part 5 of the producing apparatus 110 is formed by injecting lead from the sprue 20 of the mold 31, the mold is opened up and down at a separating part 32 and the container part 5 is taken out from the mold. Also, the lid part 4 is manufactured. The container part 5 obtained in the above manner is accommodated in the exterior container 10 as shown in Fig. 2, whereby after the radioactive solution-producing apparatus 110 is completed by providing the column 1 containing the parent radioactive nuclide, lid part 4, eluant feed means 8, radioactive solution discharge means 9, etc.

[0069] Next, a radioactive solution transportation container using the above-described radiation shielding member will be described below.

[0070] Fig. 7 indicates a radioactive solution transportation container 60 for storing a vial 63 containing a radioactive solution therein. A radiation shielding member of the transportation container 60 consists of a container part 61 and a lid part 62. The container part 61 is cylindrical, composed of a cup-like tungsten shielding body 65 having a recessed part 64 to accommodate the vial 63, and a cylindrical lead shielding body 66 surrounding a periphery 65a of the shielding body 65. The container part 61 is formed by setting the tungsten shielding body 65 in a mold and then injecting lead outside the tungsten shielding body 65. The lid part 62 is constituted of a disc-like tungsten shielding body 67 covering the tungsten shielding body 65 and a lead shielding body 68 covering an upper surface 67a and a peripheral surface 67b of the tungsten shielding body 67. A peripheral surface 66a of the lead shielding body 66, and bottom surfaces 65b and 66b of the tungsten shielding body 65 and lead shielding body 66 are coated with a plastic exterior container 69 in the container part 61. On the other hand, an upper surface 68a and a peripheral surface 68b of the lead shielding body 68 are coated with a plastic exterior container 70 on the lid part 62. The exterior containers 69 and 70 are coupled with each other when each of engaging parts 69a and 70a of the containers 69 and 70 is engaged respectively, whereby the vial 63 is fixed and sealed in the recessed part 64.

[0071] The tungsten shielding bodies 65 and 67 are exchangeable in the above constitution. Accordingly, the shielding member can be light in weight depending on the amount of radioactivity of the radioactive solution without changing the lead shielding bodies 66 and 68.

[0072] Fig. 8 represents a radioactive solution transportation container 75 of a different embodiment of the transportation container 60. The transportation container 75 uses shielding bodies 76 and 77 made of depleted uranium in place of the tungsten shielding bodies 65 and 67 of the transportation container 60. All the outer surfaces of the container

part 61 and the lid part 62 are covered with a plastic exterior container 78. The other points in structure of the transportation container 75 are the same as those of the transportation container 60 and thus the description thereof will be abbreviated here. Since every outer surface of the transportation container 75 is covered with the exterior container 78, the depleted uranium shielding bodies 76 and 77 cannot be exchanged.

[0073] The shielding member for radioactive substances according to the first aspect of the present invention constitutes the container part formed of the first shielding body and the second shielding body which has a higher shielding ability than the first shielding body. Moreover, a part of the recessed part accommodating radioactive substance is formed of the second shielding body. Therefore, the shielding member can be light in weight and compact in size while maintaining the same shielding ability as the conventional art. If the shielding member is of the same size as the shielding member in conventional art, the radiation shielding ability is enhanced, in other words, the intensity of radioactivity of radioactive substance stored in the recessed part may be increased.

[0074] The second shielding body is detachable from the first shielding body, so that the second shielding body may be exchanged with a shielding body of suitably selected thickness and material in accordance with the kind or amount of radioactivity of the radioactive substance stored in the recessed part. The radiation shielding member is fit for general purpose and economical.

[0075] The radioactive solution-producing apparatus according to the second aspect of the present invention utilizes the above radiation shielding member of the first aspect. Therefore, the apparatus is light-weight and compact while keeping the same shielding ability as the conventional one. Moreover, when the producing apparatus is constructed in the same size as the conventional one, the shielding ability against radioactive rays is increased, therefore allowing the radioactive intensity of the radioactive substance stored in the recessed part to be increased.

[0076] According to the manufacturing method for the radiation shielding member in the third aspect of the present invention, the projecting part is coated with the coupling member in the axial direction thereof between the side shielding body and the bottom shielding body. Therefore, the shielding material is prevented from invading a gap formed between the projecting part and the side shielding body when the shielding material is injected into the mold, so that the radiation shielding member can be detached easily from the mold.

Claims

1. An apparatus for preparing a radioactive solution using a radiation shielding member (101;111), said shielding member comprising: a container part (5) having a recessed part (7) defining an opening (7a) for accommodating a radioactive substance; and a lid part (4) fitted to the container part and covering the opening (7a) of the recessed part,

   wherein a bottom shielding body (52; 121) at a bottom part (5c) of the recessed part, a side shielding body (51) defining a side part of the recessed part at a position orthogonal to an axial direction of the recessed part and extending approximately 60% of a total length from an upper part of the opening (7a) through the total length of the recessed part in the axial direction in the container part, and a shielding bcdy (41, 120) disposed at a part (4c) facing to the opening of the recessed part in the lid part are formed of tungsten, with other parts of the radiation shielding member being formed of lead, the bottom shielding body (52,121) and the shielding body facing the opening (7a) in the lid part (4) having respective configurations determined in accordance with a radioactivity of the radioactive substance accommodated in the recessed part (7),
   and wherein the recessed part accommodates a column (1) storing a parent radioactive nuclide and is provided with an eluant feed means (8) connected to the column for feeding an eluant to the column and a radioactive solution discharge means (9) connected to the column for discharging a radioactive solution including a daughter radioactive nuclide eluted from the column.

2. An apparatus for preparing a radioactive solution according to claim 1, wherein, when the side shielding body (51) extends a length not fully the total length of the recessed part in the axial direction, a coupling member (122) extending in the axial direction of the recessed part thereby defining the side part of the recessed part is disposed to connect the side shielding body with the bottom shielding body.

3. An apparatus for preparing a radioactive solution according to claim 1 or 2, wherein the parent radioactive nuclide stored in the column is molybdenum-99.

4. A method for manufacturing a radiation shielding member used for an apparatus for preparing a radioactive solution comprising:

preparing a mold forming an outer shape of a container part having a recessed part defining an opening for accommodating a radioactive substance;
covering a side part of a projecting part to form the recessed part with a side shielding body formed of tungsten extending over approximately 60% of the total length from a back end of the projecting part through the total length of the projecting part in the axial direction of the projecting part;
covering a front end of the projecting part with a bottom shielding body formed of tungsten; and
injecting lead into the mold.

5. A method for manufacturing a radiation shielding member used for an apparatus for preparing a radioactive solution according to claim 4, wherein, when the side shielding body extends a length not fully the total length of the projecting part in the axial direction of the projecting part,
the method further comprising:

after the covering the side part of the projecting part and before the covering the front end of the projecting part, covering a side face of the projecting part between the side shielding body and the bottom shielding body with a coupling member, having a melting temperature higher than the melting temperature of lead, formed along the axial direction of the projecting part.

Patentansprüche

1. Vorrichtung zur Herstellung einer radioaktiven Lösung unter Verwendung eines Strahlungsabschirmteils (101; 111), wobei das Abschirmteil aufweist: ein Behälterteil (5) mit einem ausgesparten Teil (7), das eine Öffnung (7a) zum Unterbringen eines radioaktiven Stoffs bildet; und ein Deckelteil (4), das auf das Behälterteil aufgepaßt ist und die Öffnung (7a) des ausgesparten Teils abdeckt,

wobei ein Bodenabschirmkörper (52; 121) an einem Bodenteil (5c) des ausgesparten Teils, ein Seitenabschirmkörper (51), der ein Seitenteil des ausgesparten Teils an einer Position senkrecht zu einer Axialrichtung des ausgesparten Teils bildet und sich über etwa 60 % einer Gesamtlänge von einem Oberteil der Öffnung (7a) über die Gesamtlänge des ausgesparten Teils in Axialrichtung in dem Behälterteil erstreckt, und ein Abschirmkörper (41, 120), der an einem zu der Öffnung des ausgesparten Teils weisenden Teil (4c) in dem Deckelteil angeordnet ist, aus Wolfram ausgebildet sind, wobei andere Teile des Strahlungsabschirmteils aus Blei ausgebildet sind,
wobei der Bodenabschirmkörper (52; 121) und der zu der Öffnung (7a) weisende Abschirmkörper in dem Deckelteil (4) jeweilige Konfigurationen haben, die in Übereinstimmung mit einer Radioaktivität des in dem ausgesparten Teil (7) untergebrachten radioaktiven Stoffs bestimmt sind,
und wobei das ausgesparte Teil eine Säule (1) enthält, in der ein radioaktives Mutternuklid untergebracht ist, und versehen ist mit einer Eluentzuflußeinrichtung (8), die mit der Säule verbunden ist, zum Zuführen eines Eluenten zu der Säule sowie einer Abflußeinrichtung (9) für radioaktive Lösung, die mit der Säule verbunden ist, zum Abführen einer radioaktiven Lösung, die ein aus der Säule eluiertes radioaktives Tochternuklid aufweist.

2. Vorrichtung zur Herstellung einer radioaktiven Lösung nach Anspruch 1, wobei in dem Fall, daß sich der Seitenabschirmkörper (51) über eine Länge erstreckt, die nicht vollständig der Gesamtlänge des ausgesparten Teils in Axialrichtung entspricht, ein sich in Axialrichtung des ausgesparten Teils erstreckendes und dadurch das Seitenteil des ausgesparten Teils bildendes Koppelteil (122) so angeordnet ist, daß es den Seitenabschirmkörper mit dem Bodenabschirmkörper verbindet.

3. Vorrichtung zur Herstellung einer radioaktiven Lösung nach Anspruch 1 oder 2, wobei das in der Säule untergebrachte radioaktive Mutternuklid 99-Molybdän ist.

4. Verfahren zur Herstellung eines Strahlungsabschirmteils, das für eine Vorrichtung zur Herstellung einer radioaktiven Lösung verwendet wird, mit den folgenden Schritten:

Vorbereiten einer Form, die eine Außenform eines Behälterteils mit einem eine Öffnung bildenden ausgesparten Teil zum Unterbringen eines radioaktiven Stoffs bildet; Abdecken eines Seitenteils eines vorstehenden Teils zum Bilden des ausgesparten Teils mit einem aus Wolfram gebildeten Seitenabschirmkörper, der sich über etwa 60 % der Gesamtlänge von einem hinteren Ende des vorstehenden Teils über die Gesamtlänge

des vorstehenden Teils in Axialrichtung des vorstehenden Teils erstreckt;
Abdecken eines vorderen Endes des vorstehenden Teils mit einem aus Wolfram gebildeten Bodenabschirmkörper; und Einspritzen von Blei in die Form.

5. Verfahren zur Herstellung eines für eine Vorrichtung zur Herstellung einer radioaktiven Lösung verwendeten Strahlungsabschirmteils nach Anspruch 4, wobei in dem Fall, daß sich der Seitenabschirmkörper über eine Länge erstreckt, die nicht vollständig der Gesamtlänge des vorstehenden Teils in Axialrichtung des vorstehenden Teils entspricht, das Verfahren ferner den folgenden Schritt aufweist:

   nach Abdecken des Seitenteils des vorstehenden Teils und vor Abdecken des vorderen Endes des vorstehenden Teils erfolgendes Abdecken einer Seitenfläche des vorstehenden Teils zwischen dem Seitenabschirmkörper und dem Bodenabschirmkörper mit einem Koppelteil, das eine höhere Schmelztemperatur als die Schmelztemperatur von Blei hat und in Axialrichtung des vorstehenden Teils ausgebildet ist.

Revendications

1. Dispositif pour la préparation d'une solution radioactive utilisant un élément de protection contre les radiations (101 ; 111), ledit élément de protection comportant : une partie formant conteneur (5) ayant une partie évidée (7) définissant une ouverture (7a) pour recevoir une substance radioactive, et une partie formant couvercle (4) fixée à la partie formant conteneur et recouvrant l'ouverture (7a) de la partie évidée,

   dans lequel un corps de protection inférieur (52 ; 121) dans une partie inférieure (5c) de la partie évidée, un corps de protection latéral (51) définissant une partie latérale de la partie évidée dans une position perpendiculaire à une direction axiale de la partie évidée et s'étendant sur approximativement 60 % de la longueur totale depuis une partie supérieure de l'ouverture (7a) sur la longueur totale de la partie évidée dans la direction axiale dans la partie formant conteneur, et un corps de protection (41, 120) disposé dans une partie (4c) faisant face à l'ouverture de la partie évidée dans la partie formant couvercle, sont constitués de tungstène, d'autres parties de l'élément de protection contre les radiations étant constituées de plomb, le corps de protection inférieur (52 ; 121) et le corps de protection faisant face à l'ouverture (7a) dans la partie formant couvercle (4) ayant des configurations respectives déterminées conformément à une radioactivité de la substance radioactive reçue dans la partie évidée (7),
   et dans lequel la partie évidée reçoit une colonne (1) stockant des noyaux radioactifs parents et est munie de moyens d'alimentation en éluant (8) connectés à la colonne pour envoyer un éluant dans la colonne et de moyens de décharge de solution radioactive (9) connectés à la colonne pour décharger une solution radioactive comportant des noyaux radioactifs enfants élués de la colonne.

2. Dispositif pour la préparation d'une solution radioactive selon la revendication 1, dans lequel, lorsque le corps de protection latéral (51) s'étend sur une longueur qui n'est pas pleinement la longueur totale de la partie évidée dans la direction axiale, un élément de couplage (122) s'étendant dans la direction axiale de la partie évidée définissant ainsi la partie latérale de la partie évidée est disposé pour connecter le corps de protection latéral au corps de protection inférieur.

3. Dispositif pour la préparation d'une solution radioactive selon la revendication 1 ou 2, dans lequel le noyau radioactif parent stocké dans la colonne est du molybdène-99.

4. Procédé de fabrication d'un élément de protection contre les radiations utilisé pour un dispositif pour la préparation d'une solution radioactive, comportant les étapes consistant à :

   préparer un moule formant une forme extérieure d'une partie formant conteneur ayant une partie évidée définissant une ouverture destinée à recevoir une substance radioactive,
   recouvrir une partie latérale d'une partie en saillie pour former la partie évidée à l'aide d'un corps de protection latéral constitué de tungstène s'étendant sur approximativement 60 % de la longueur totale depuis l'extrémité arrière de la partie en saillie sur la longueur totale de la partie en saillie dans la direction axiale de la partie en saillie,
   recouvrir une extrémité avant de la partie en saillie à l'aide d'un corps de protection inférieur constitué de tungstène, et
   injecter du plomb dans le moule.

5. Procédé de fabrication d'un élément de protection contre les radiations utilisé pour un dispositif pour la préparation d'une solution radioactive selon la revendication 4, dans lequel, lorsque le corps de protection latéral s'étend sur une longueur qui n'est pas pleinement la longueur totale de la partie en saillie dans la direction axiale de la partie en saillie,

le procédé comporte de plus l'étape consistant à :

après avoir recouvert la partie latérale de la partie en saillie et avant de recouvrir l'extrémité avant de la partie en saillie, recouvrir une face latérale de la partie en saillie entre le corps de protection latéral et le corps de protection inférieur à l'aide d'un élément de couplage, ayant une température de fusion supérieure à la température de fusion du plomb, formé le long de la direction axiale de la partie en saillie.

F I G. 1

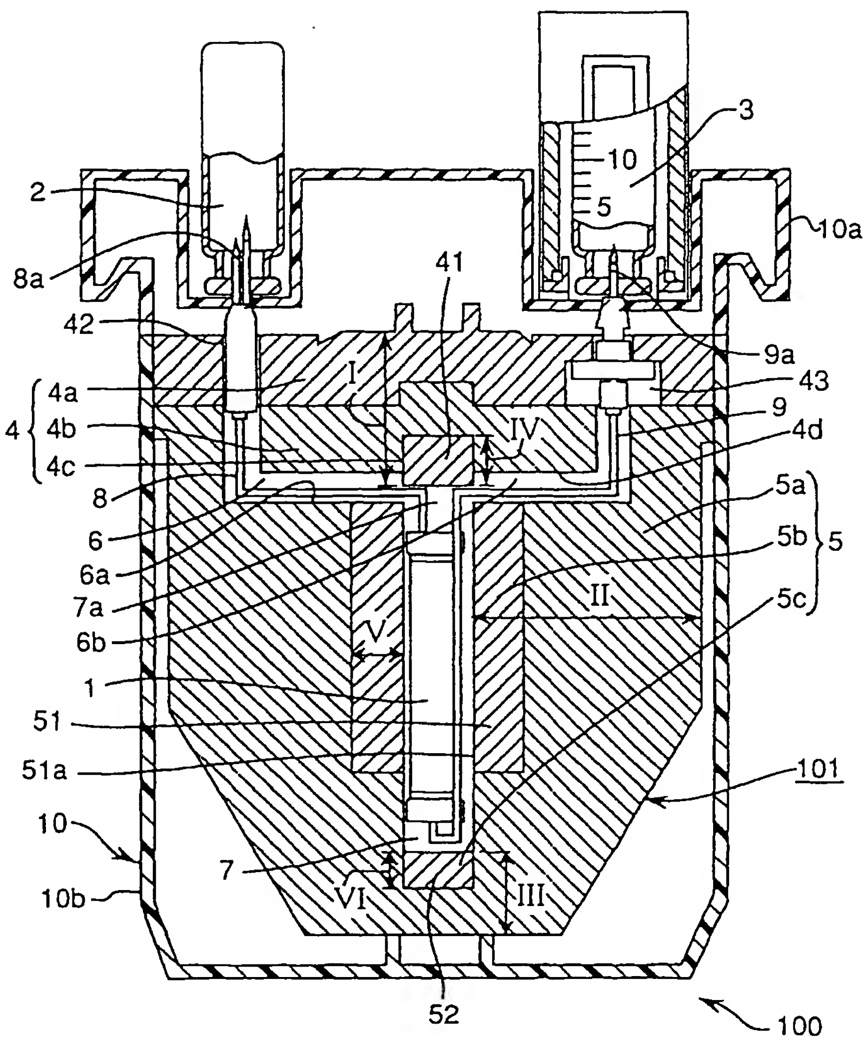
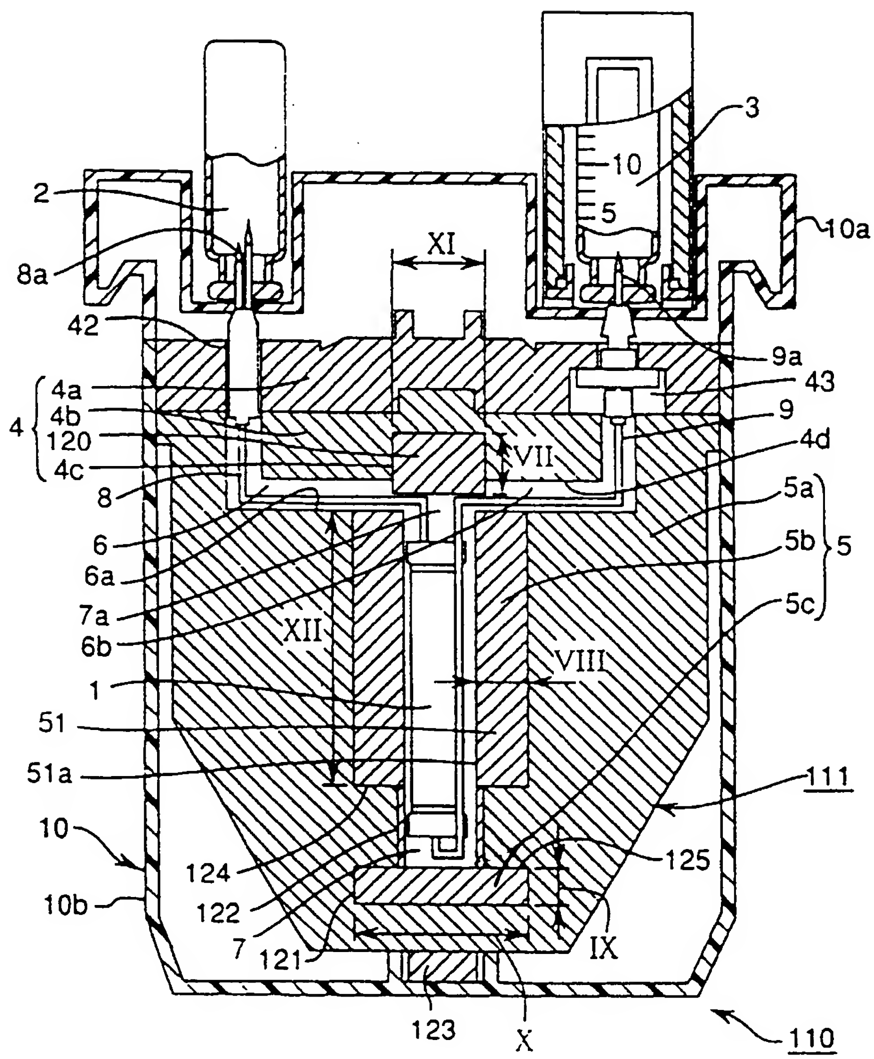
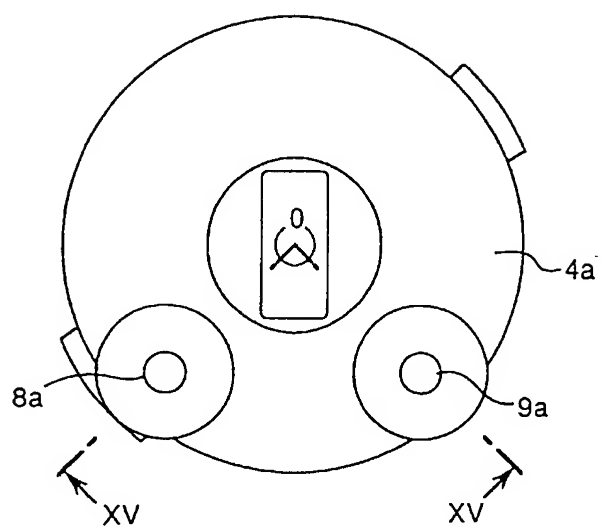

2
8a
42
4
4a
4b
4c
8
6
6a
7a
6b
1
51
51a
10
10b
7
VI
III
52
100
101
41
I
IV
II
V
3
10
5
10a
9a
43
9
4d
5a
5b
5
5c

FIG. 2

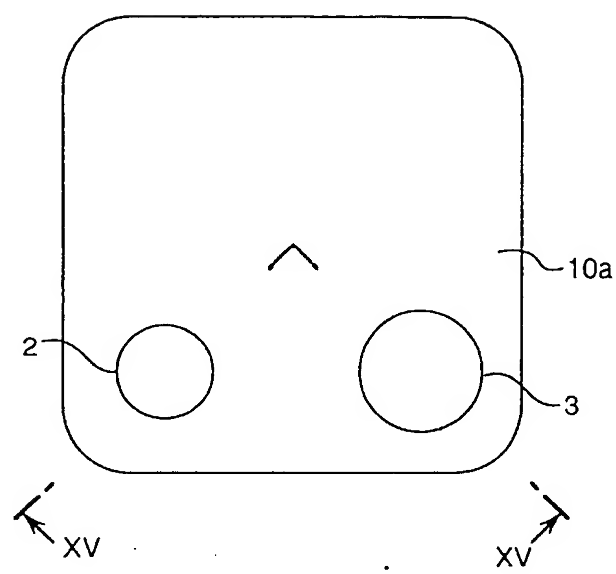


2
8a
42
4a
4b
4
120
4c
8
6
6a
7a
6b
1
51
51a
10
10b
124
122
7
121
123
X
110
IX
125
111
5c
5b
5a
5
4d
9
43
9a
10a
3
10
5
XI
VII
XII
VIII

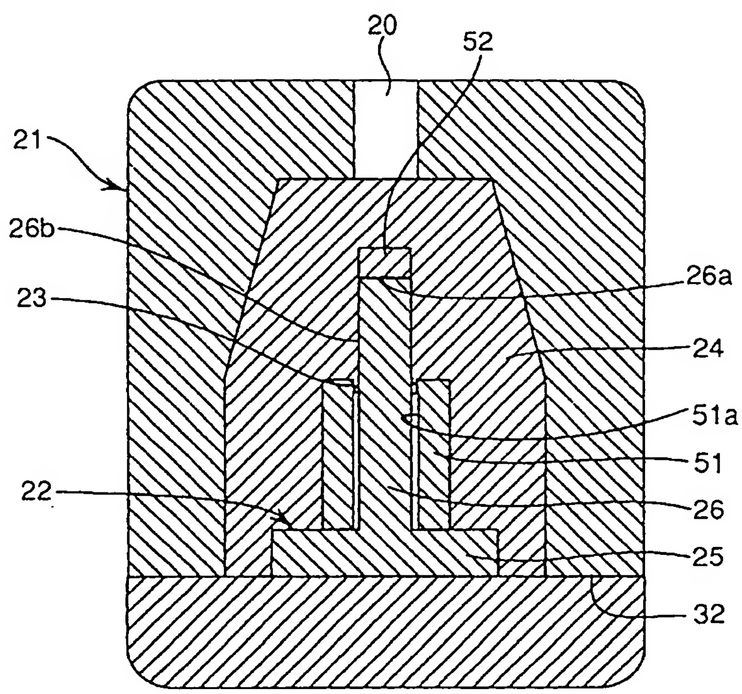
F I G. 3



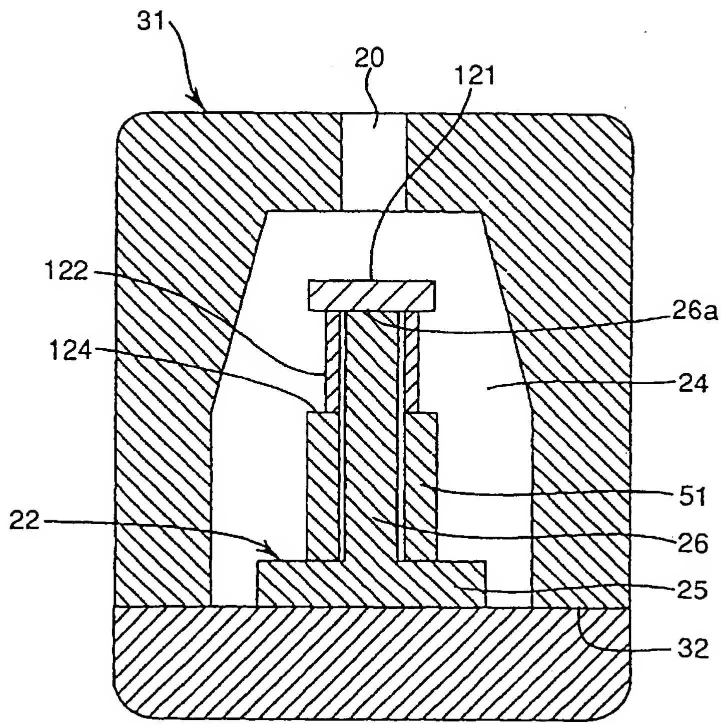
F I G. 4



F I G. 5



F I G. 6



F I G. 7

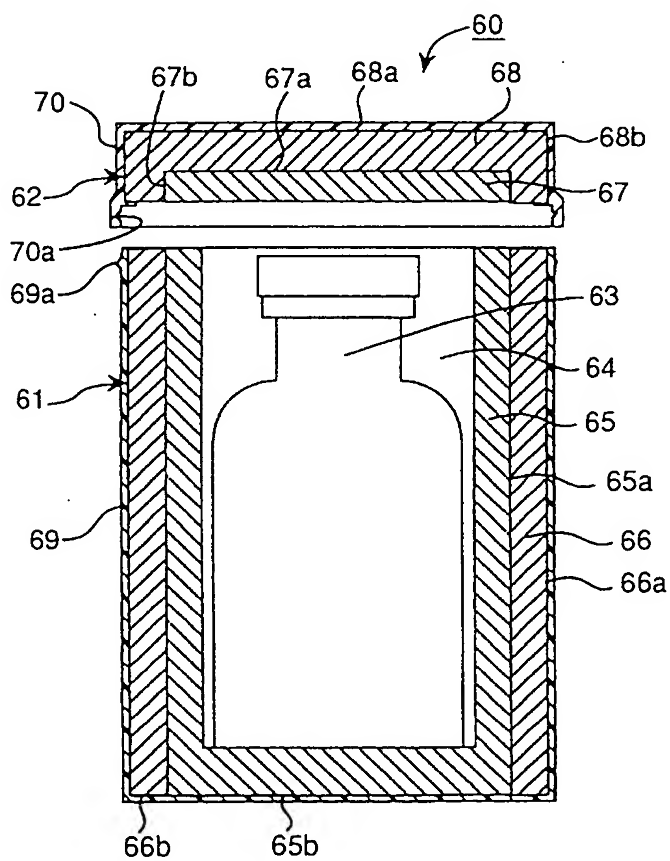
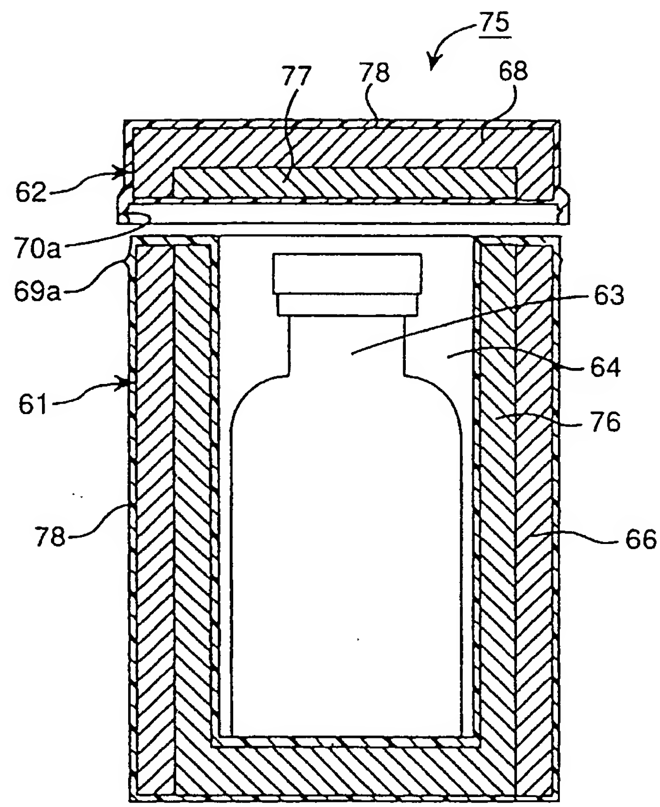
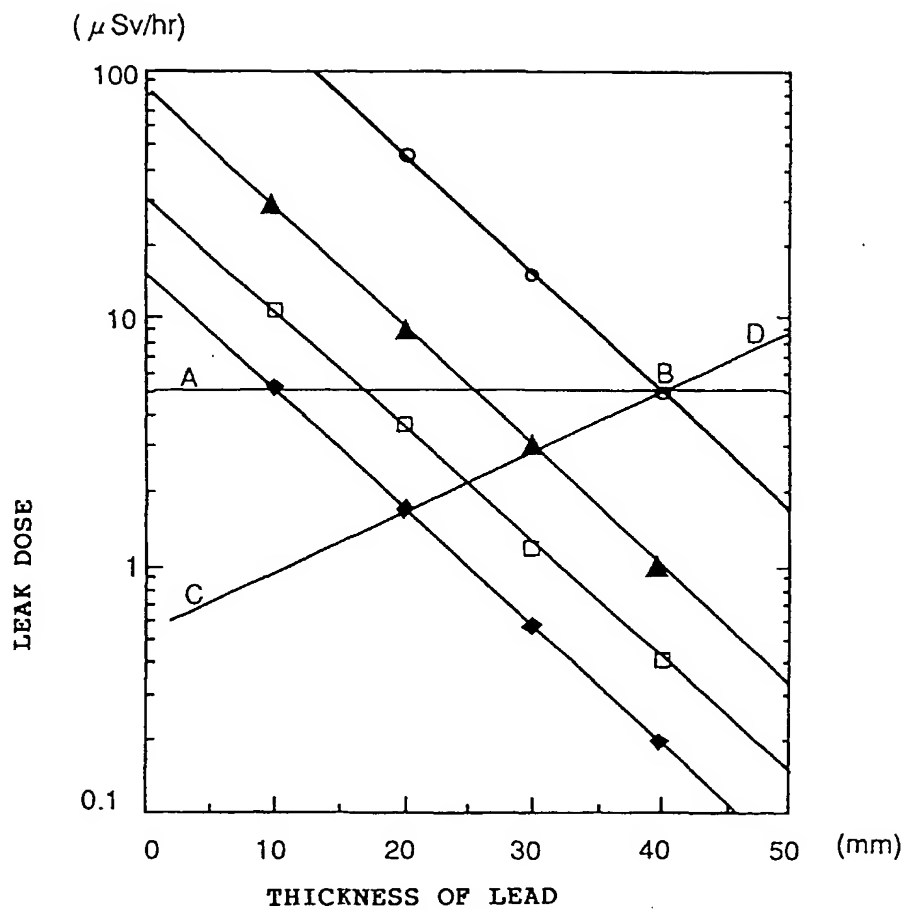

60
67b
67a
68a
68
70
68b
62
67
70a
69a
63
64
61
65
65a
69
66
66a
66b
65b

FIG. 8

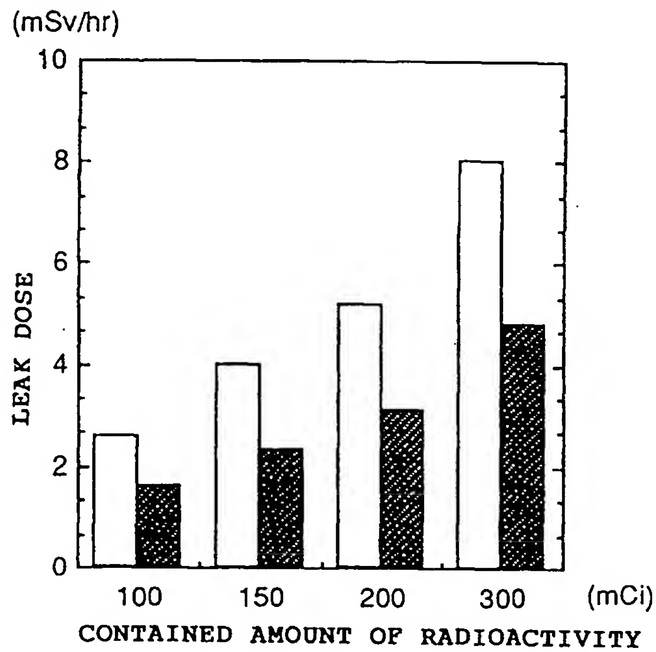


F I G. 9



○ LEAD ONLY
▲ LEAD+ TUNGSTEN OF 10mm
□ LEAD+ TUNGSTEN OF 15mm
◆ LEAD+ TUNGSTEN OF 20mm

FIG. 10



□ LEAD 40mm
(THIS CONSTITUTION CORRESPONDS TO THE 1ST CONTAINER.)

▨ LEAD 30mm+ TUNGSTEN 10mm
(THIS CONSTITUTION CORRESPONDS TO THE 11THE CONTAINER.)